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CNS Simulation Tool Development for Increasingly Complex Airspace Operation Evaluation

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Presentation Outline

1. Introduction
2. SMART NAS Testbed Background
3. SMART NAS Testbed Architecture
4. CNS Model Development & Design
5. Evaluation Results
6. Conclusion

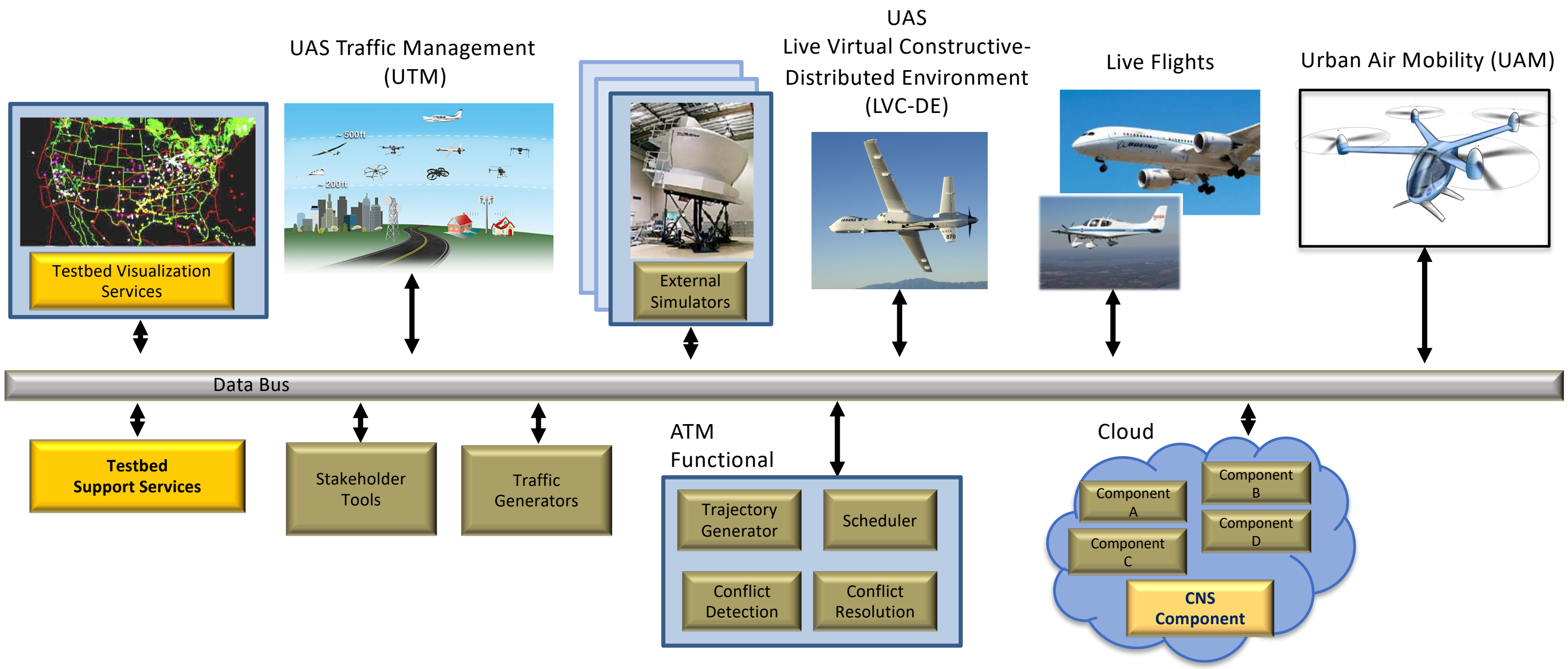
Introduction

- NASA Shadow Mode Assessment using Realistic Technologies for the National Airspace System (SMART NAS) initiated Test Bed Development
- Under the Air Traffic Management eXploration (ATM-X) Project, NASA is continuing testbed modernization and expanded development of new simulation tools and capabilities to include operations for new airspace users
  - Evaluation of new Air Traffic concepts, technologies and vehicles with new missions seeking entry into the airspace requires the use of simulation capabilities not currently available
- Purpose is to conduct high-fidelity, real-time, human-in-the-loop and automation-in-the-loop simulations
- This presentation describes CNS simulation architecture and software design developmental efforts

CNS Simulation Background

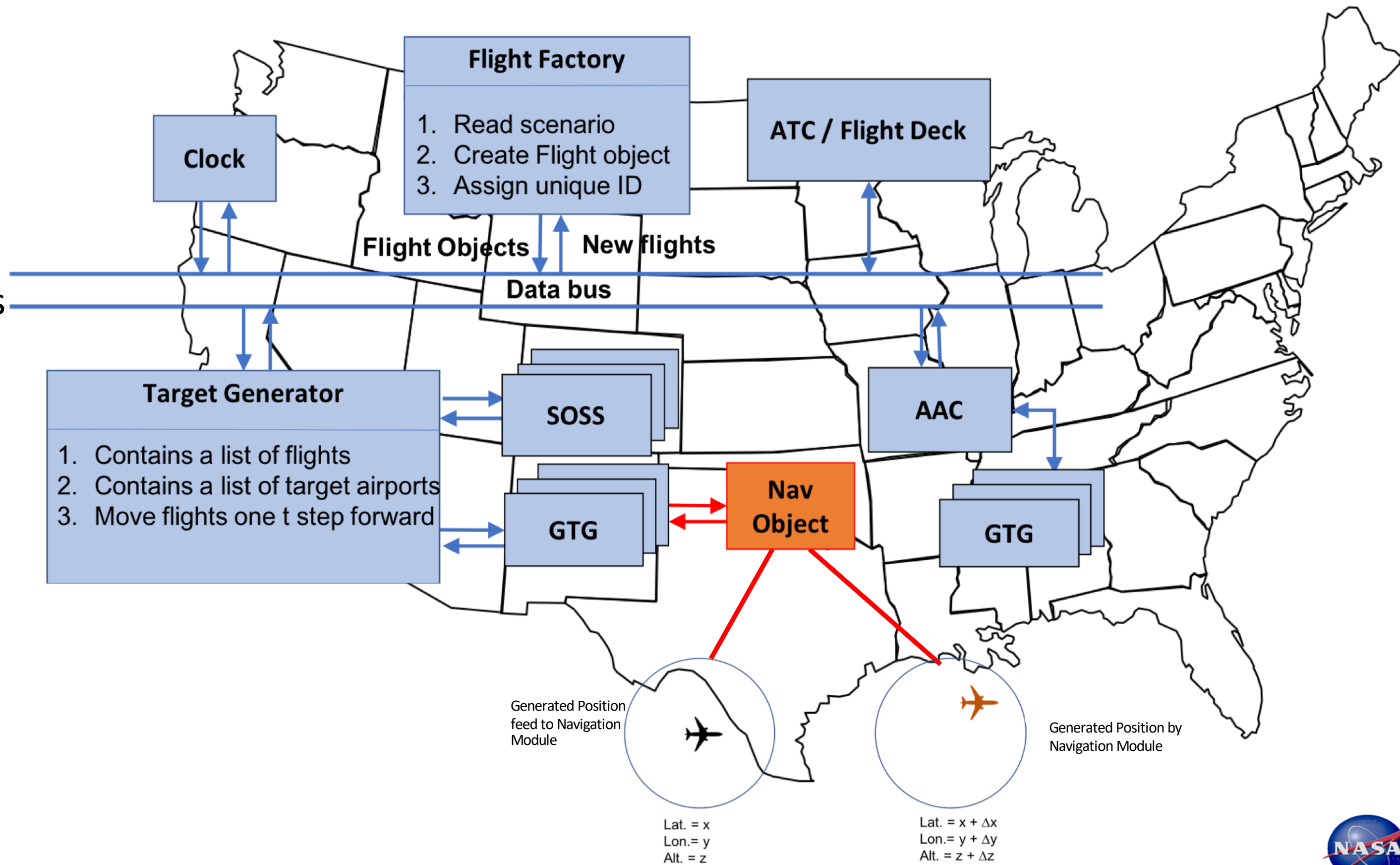
- NAS depends on CNS systems to deliver ATM services and these technologies have performance and reliability limitations
- Modern and vintage CNS technologies used today e.g. VOR-DME, GPS
- CNS simulation is required for optimal system architecture design, risk mitigation, operational efficiency, service degradation evaluation, and more.
- CNS modeling provides scalability analysis, efficiency performance, realistic assessment and assist in proof of ATM Concepts
- NASA Glenn Research Center is developing CNS tools to evaluate existing and future ATM concepts that considers existing and new vehicle operations.

Testbed Architectural Elements



CNS Model Development

- Navigation Module designed as a submodule of Target Generator
- Navigation Module adds uncertainty to the track
- Provides adjustable parameters for aircraft position variability
- Provides position generation using statistical approximations



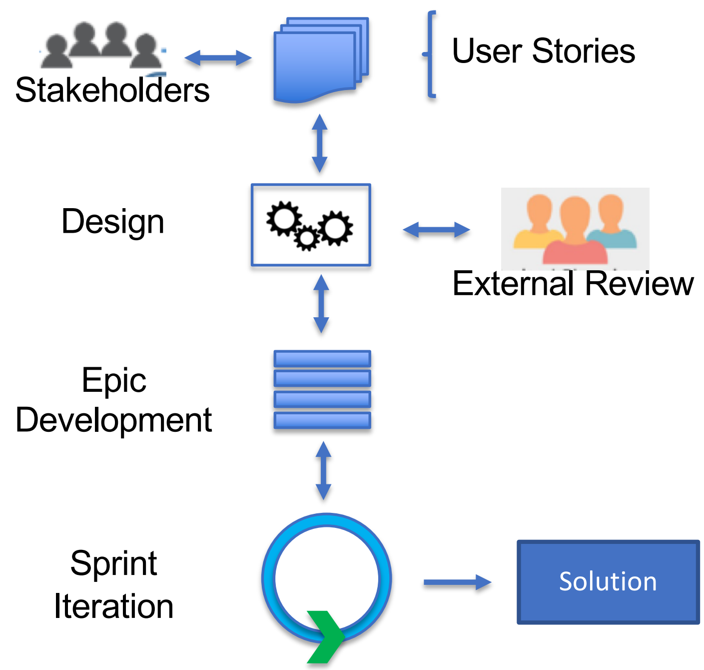
CNS Model Development

- Development code written in the programming language of Java, using OpenJDK 11.
- Coding standards based on SMART NAS Testbed's (SNTB) Java coding standards.
- Atlassian collaboration products employed such as Jira®, Confluence®, Bitbucket®, and FishEye®.
- *Agile* style approach for software development and project management.

Software Engineering Development

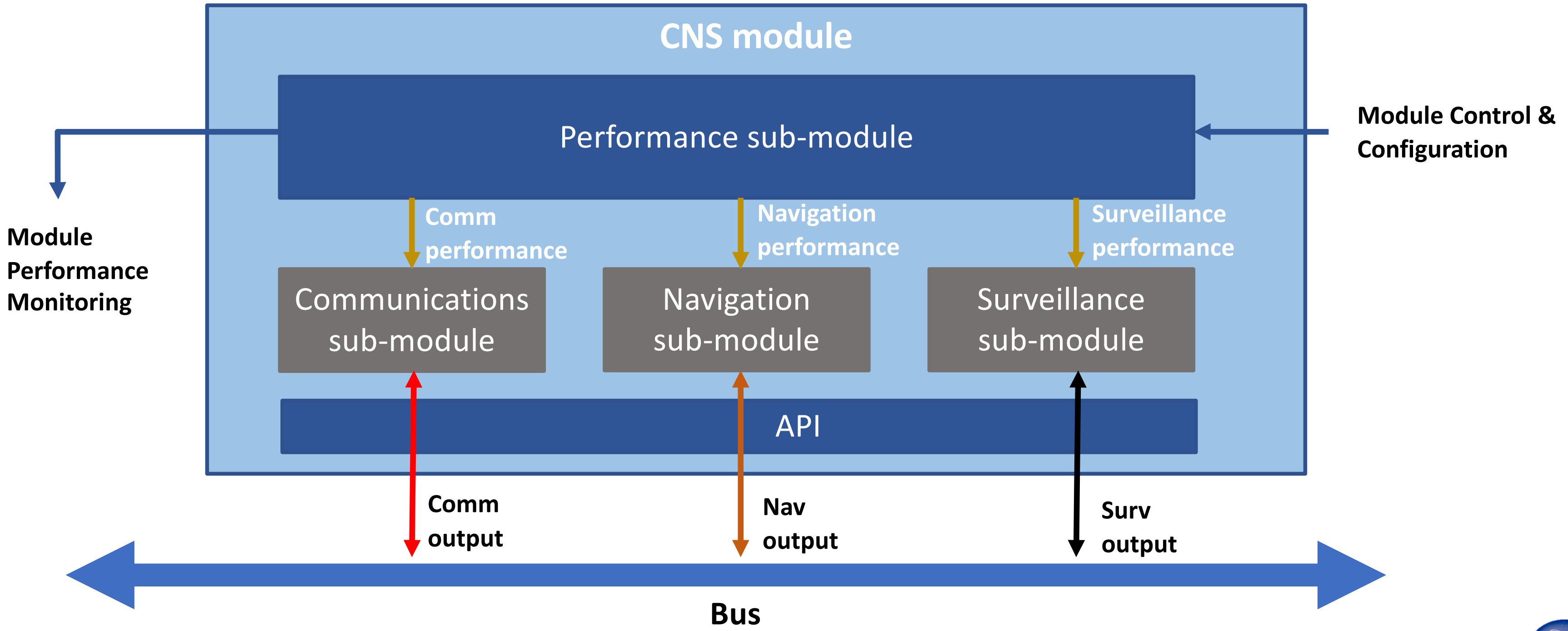
Agile Approach for Testbed Development

- User stories development & priority assignment
- User story implementation design
- External Review
- User story task decomposition into tasks – Epic assignment
- Sprint Iteration – coding/testing
- Demonstration to Stakeholders
- Release solution into production



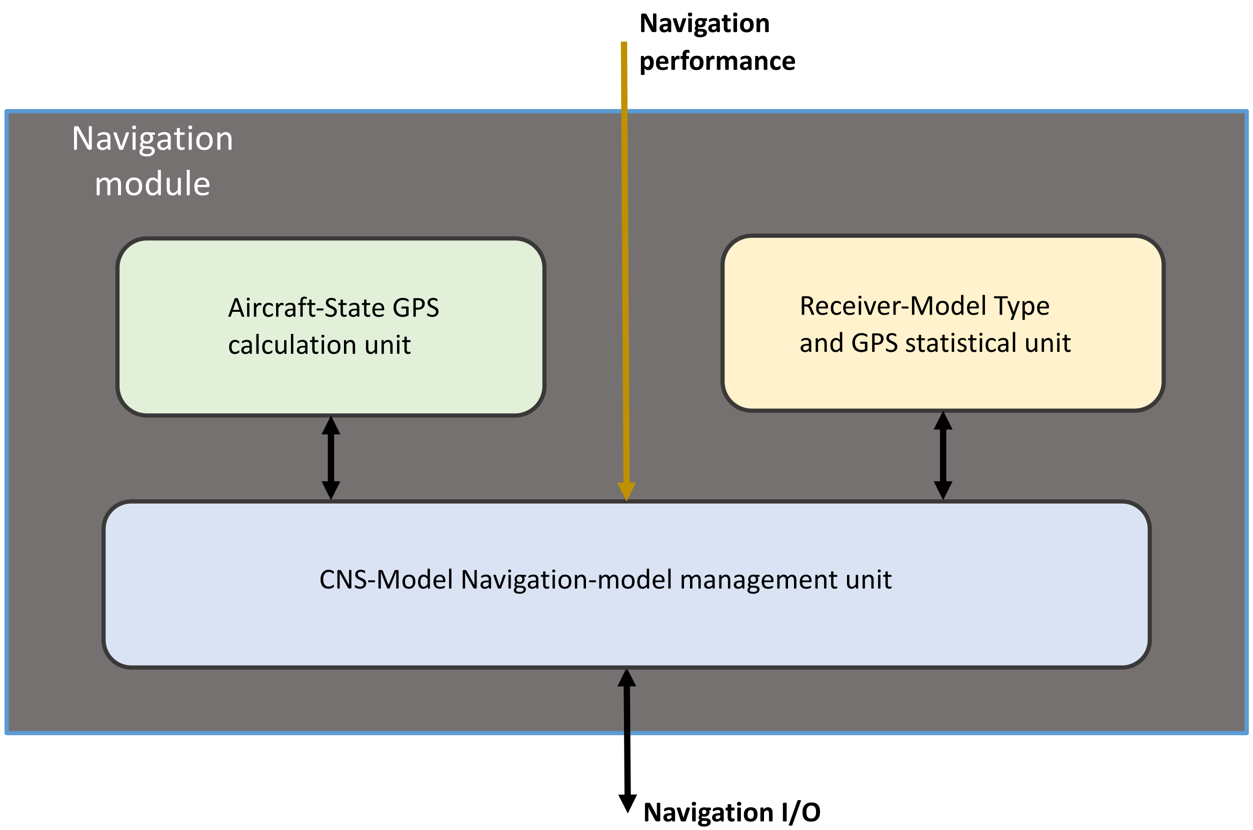
CNS Module Architecture

High level notional CNS module



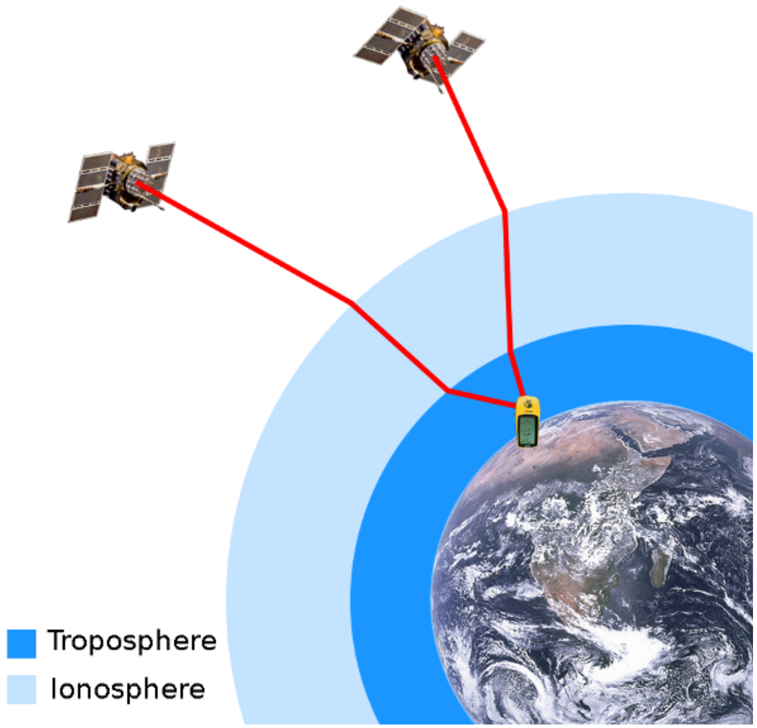
Navigation Module Architecture

- **Management Unit** – Controls *request* and *response* between the TG and Nav Object, as well as data exchange between internal units.
- **GPS Calculation Unit** – Holds the current state of the aircraft and calculates the GPS position with applied error based on the input (x, y, z) and GPS errors from the GPS Statistical Unit.
- **GPS Statistical Unit** – Holds the values for inherent GPS errors and a ReceiverType.

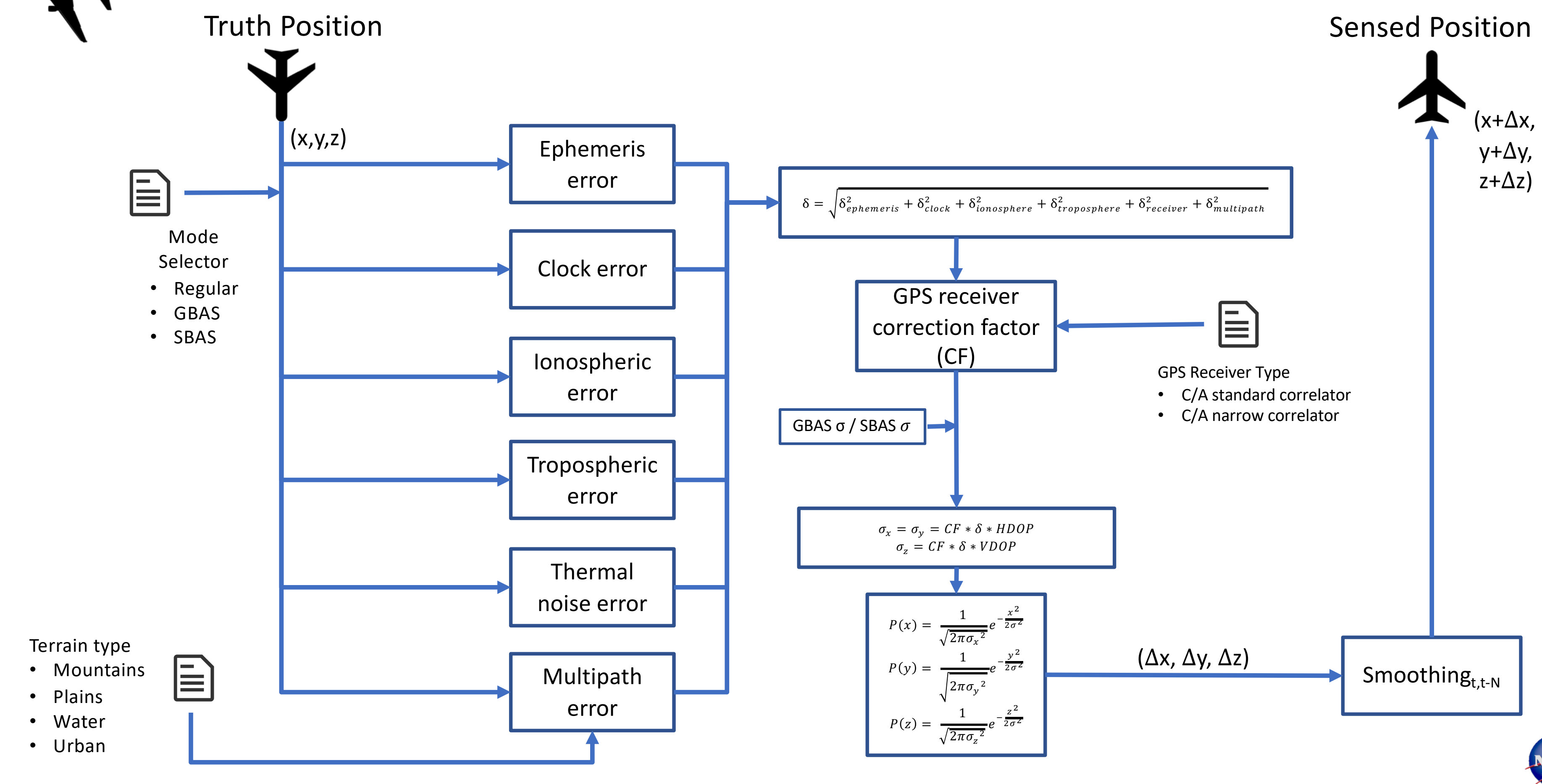


Model Design Error Considerations

- **Ephemeris** - Errors in the transmitted location of the satellite.
- **Clock** - Residual errors from clock drift and noise in the transmitted clock.
- **Ionospheric** - Errors caused by the signal transmission through the Ionosphere.
- **Tropospheric** - Errors caused by the signal transmission through the Troposphere.
- **Thermal noise** – Errors caused by the receiver's thermal noise.
- **Multipath** - Errors caused by reflected signals entering the receiver antenna.

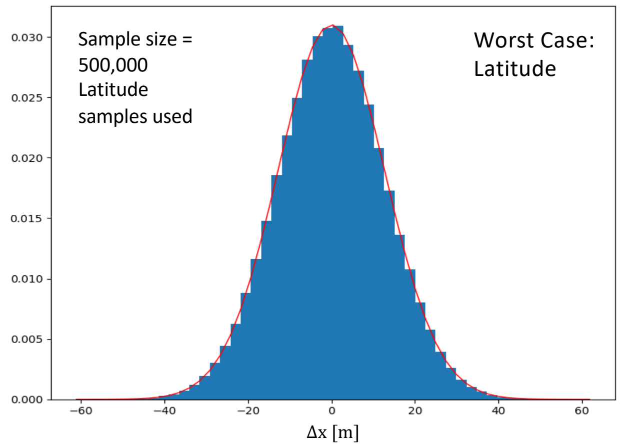


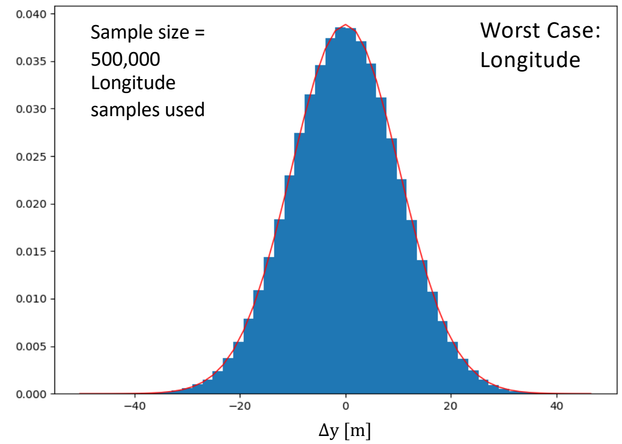
Module Design – Position Determination



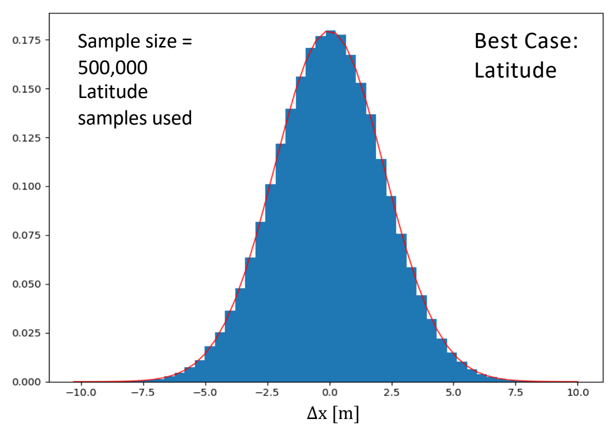
Navigation Module Evaluation

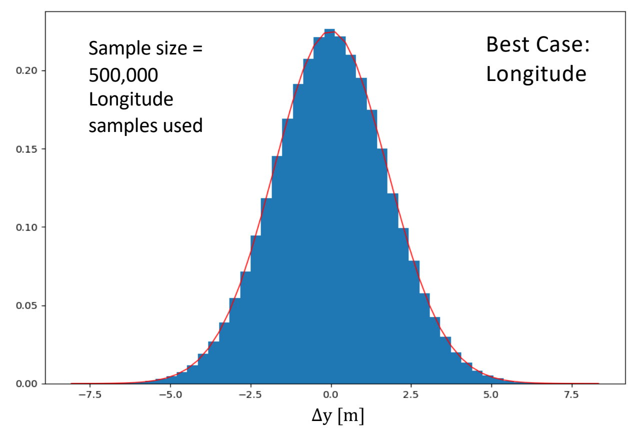
GPS error applied to the true position





Max Latitude Error:	87.0558	meters
Max Longitude Error:	67.2873	meters
Max Altitude Error:	133.6660	meters
Min Latitude Error:	-71.3894	meters
Min Longitude Error:	-67.0877	meters
Min Altitude Error:	-108.8807	meters
Mean Latitude Error:	-0.0172	meters
Mean Longitude Error:	0.0028	meters
Mean Altitude Error:	0.0066	meters
StdDev Latitude Error:	12.8611	meters
StdDev Longitude Error:	10.2665	meters
StdDev Altitude Error:	13.6646	meters

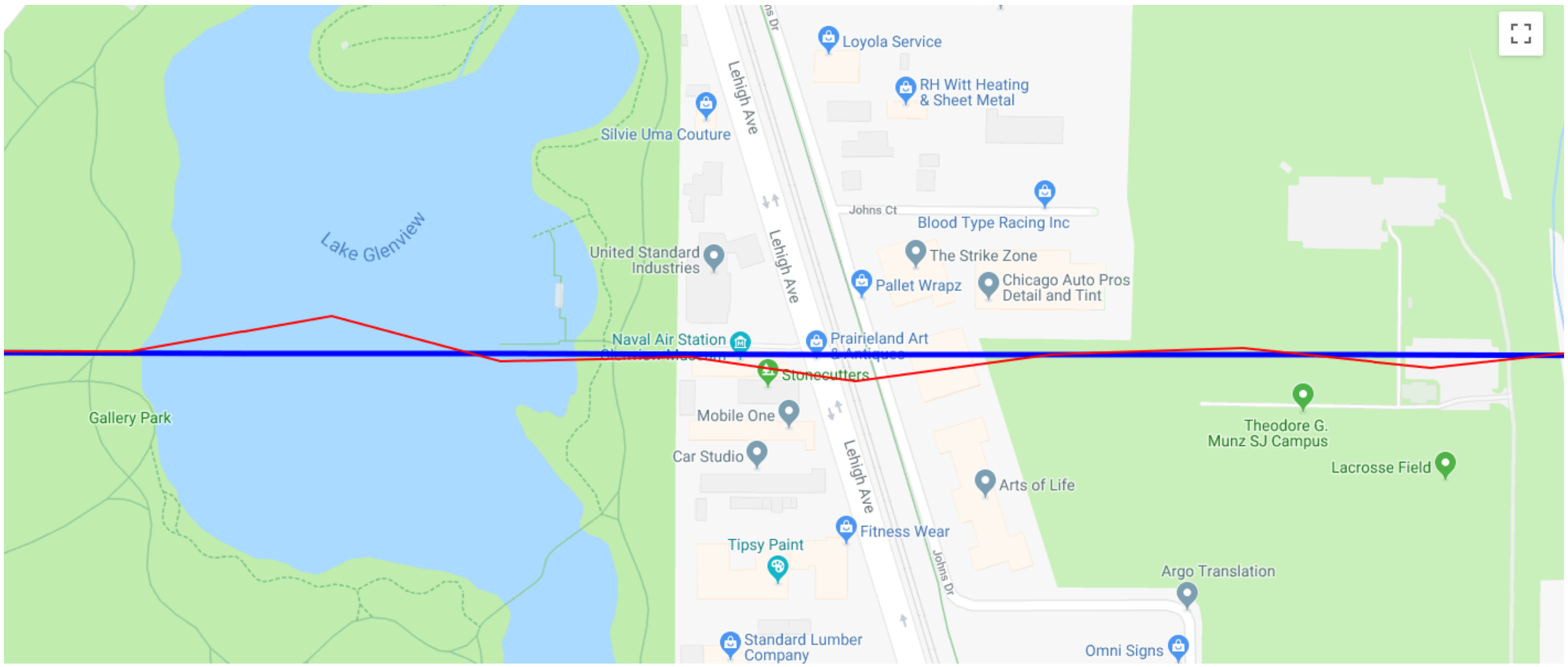




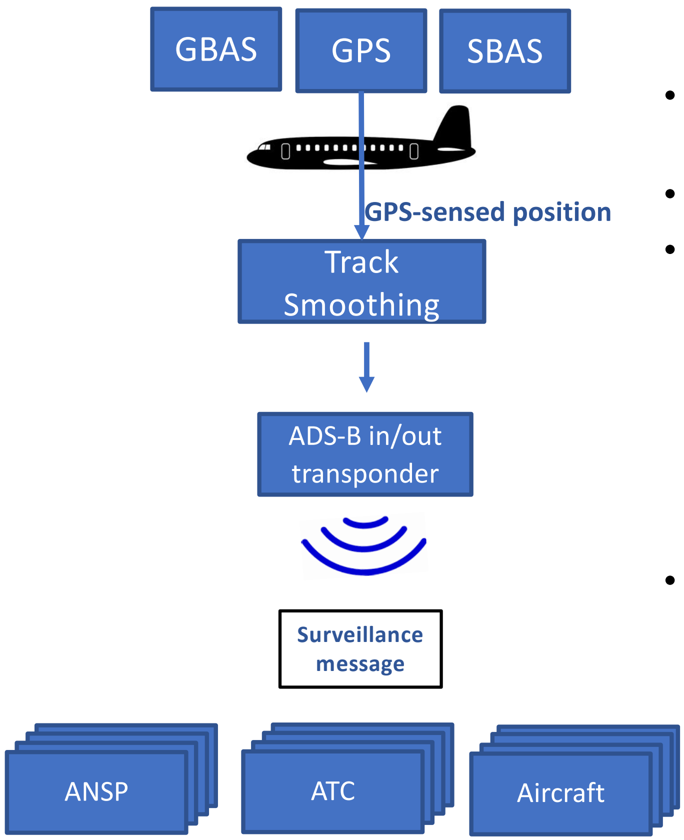
Max Latitude Error:	11.7612	meters
Max Longitude Error:	9.2523	meters
Max Altitude Error:	18.1641	meters
Min Latitude Error:	-11.2876	meters
Min Longitude Error:	-9.7336	meters
Min Altitude Error:	-16.8812	meters
Mean Latitude Error:	-0.0019	meters
Mean Longitude Error:	-0.0003	meters
Mean Altitude Error:	0.0037	meters
StdDev Latitude Error:	2.2216	meters
StdDev Longitude Error:	1.7719	meters
StdDev Altitude Error:	2.3669	meters

Navigation Module Evaluation

KML overview with Blue = Truth_Position, Red = Sensed_Position



Next Phases



- Implement satellite based augmentation and ground based augmentation
- Develop and implement Track Smoothing capability
- Implement air-ground ADS-B Out/In
  - Transmits GPS position calculated by basic airborne sensed position module
  - Non-ideal availability, latency and message drop
  - Statistical distance between aircraft and ground station
  - Independent to the realistic characterization of GPS accuracy in basic module
- Development of air-ground surveillance modules
  - Cooperative radar (SSR – PSR + Mode-S)
  - Airport Surface Detection (ASDE)

Conclusions

- A new suit of tools are required to evaluate future concepts of operations and meet the fast evolving demand for new vehicle entries and their operations in the NAS
- Under the SMART NAS project, NASA started the effort to develop state of the art capabilities to meet new challenges and demands for expediting complex concept evaluation.
- A simulation environment that evaluates complex operations in a realistic environment needs to be user friendly, interoperable with existing and new tools, modular, have adequate fidelity, security, scalability and cost effective.
- NASA Glenn Research Center is developing new and improved CNS simulation tools for a realistic evaluation of ATM concepts for existing and new vehicle operations.